

International Journal of Agriculture Extension and Social Development

Volume 9; Issue 6; June 2026; Page No. 29-40

Received: 07-03-2026
Accepted: 13-04-2026

Indexed Journal
Peer Reviewed Journal

Analysis of trends in arrivals and prices of arecanut in selected markets of Karnataka

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DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i6a.3657>

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Abstract

Aim: To analyse the trends in arrivals and prices of arecanut in selected major markets of Karnataka and identify the most suitable models for describing long-term market behaviour.

Study Design: The study utilized annual arrivals and modal price data of arecanut from five major markets of Karnataka, namely Shivamogga, Sirsi, Sagara, Channagiri, and Yellapura, covering the period from 2007 to 2023. Linear and non-linear trend models were fitted and compared using statistical criteria.

Place and Duration of Study: The study was conducted using secondary data collected from Krishi Marata Vahini and AGMARK databases for the period January 2007 to December 2023.

Methodology: Monthly data on arrivals (tonnes) and modal prices (Rs./quintal) were collected and aggregated into annual data. Time series analysis was employed to study long-term movements in arrivals and prices. Linear, Quadratic, Cubic, Exponential, Logistic, and Gompertz models were fitted using R software. Model adequacy was evaluated using Run Test and Shapiro-Wilk Test, while model selection was based on the highest coefficient of determination (R^2) and lowest Root Mean Square Error (RMSE).

Results: The analysis revealed no significant long-term trend in arecanut arrivals across the selected markets, indicating that arrivals were influenced by factors not captured by the fitted models. In contrast, prices exhibited a strong non-linear increasing trend. The Logistic model was identified as the best-fitting model for price trends in Shivamogga, Sirsi, Sagara, and Yellapura markets, with R^2 values ranging from 0.89 to 0.91. For the Channagiri market, the Gompertz model provided the best fit with an R^2 value of 0.9069 and RMSE of 41.35. The results indicate that arecanut prices increased substantially during the study period, with growth rates gradually slowing as prices approached stabilization levels.

Conclusion: The study concluded that while arecanut arrivals did not exhibit a consistent trend, prices followed significant non-linear growth patterns. Logistic and Gompertz models effectively captured the long-term price behaviour of arecanut in the selected markets and can be useful tools for forecasting future price movements.

Recommendation: Regular monitoring of market arrivals and prices using advanced trend models is recommended to improve price forecasting and assist farmers, traders, and policymakers in making informed production, marketing, and policy decisions.

Keywords: Arecanut, market arrivals, price trend, Karnataka markets, time series analysis, logistic model, Gompertz model, RMSE, price forecasting

1. Introduction

Arecanut (*Areca catechu* Linn) is an important cash crop for India. It belongs to the family Arecaceae. The economic produce is the fruit called betel nut, which is employed primarily for masticatory purposes. It provides income and livelihood security to many people in India. Being a highly profitable commercial plantation crop, it is important to comprehend the practices to be followed and adopted to maximize returns.

Indians chew the raw kernel when it's tender, ripe, or processed. It is processed and utilized to make products like

pan masala, gutkha, perfumed supari, and others that are gaining popularity throughout the nation. We can witness the use of arecanut dating back to the Vedic era when they were first cultivated.

The price of arecanut, a vital cash crop in India, plays a significant role in the livelihoods of millions of farmers, particularly in states like Karnataka, Kerala, Assam, and West Bengal, where its cultivation is concentrated. Arecanut prices have been subject to considerable fluctuations due to a variety of factors, making it essential to understand the underlying dynamics. The prices are influenced by domestic

demand, which is largely driven by its use in various forms such as raw kernel (chewed as betel nut), processed arecanut in pan masala, guthka, and scented supari. The growing popularity of these products has had a direct impact on the arecanut market value.

India is the major producer of arecanut which accounts for 50 per cent of production and 43 per cent of area arecanut in the world. Other major producers are South and Southeast Asian countries such as Bangladesh, Myanmar, Indonesia, China, Sri Lanka, and Thailand. In 2020, the world arecanut production was 17.96 lakh Tonnes from an area of 12.26 lakh hectares with an average yield level of 1.46 Tonnes/ha.

In India, arecanut is cultivated on around 7.7 lakh hectares area with an annual production of 14 lakh tones and a yield level of 1.8 t/ha (2021-22). Andhra Pradesh, Assam, Meghalaya, Tripura, Andaman and Nicobar Islands, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Mizoram, West Bengal, and Pondicherry are the states in India where arecanut are farmed mostly. Furthermore, a sizeable share belongs to the states of Karnataka and Kerala, which together account for more than 80 per cent of the country's arecanut output and area. Karnataka is the state with the largest area (0.5 Mha) covered by arecanut, producing 0.54 mt of arecanut produce in 2020-21. Kerala comes in second with an area of 0.09 ha and a production of 0.092 mt, Assam with an area of 0.067 Mha and a production of 0.05 mt, Meghalaya with an area of 0.017 Mha and a production of 0.024 mt, and West Bengal with an area of 0.011 Mha and a production of 0.023 mt (NHB, 2021) ^[2].

Among the states in India, the highest rate of arecanut is grown in Karnataka. According to official statistics, areca is cultivated in several Karnataka districts. In Karnataka, arecanut is farmed for financial gain, and cultivators invest their whole lives in the growth and upkeep of the plant. In Karnataka, the districts of South Kanara, North Kanara, Udupi, Shivamogga, and Chikkamagaluru are the main locations for arecanut farming due to their abundant rainfall. arecanut is also widely produced in plains districts like Davanagere, Tumkur, and Chitradurga; they are also grown in some areas of the Karnataka districts of Hassan, Mandya, Mysore, and Kodagu. Among Karnataka's districts, Shivamogga led the way in both area (0.10 Mha) and production (2.36 lakh tonnes) during 2020-21, followed by Dakshina Kannada and Davanagere. Farmers in Karnataka have responded positively to price stimulus by increasing the area under cultivation as arecanut prices have risen. About 45 per cent of the entire production comes from plain land areas, 40 per cent from coastal belt regions, and the remaining 15 per cent comes from other districts.

The arecanut varieties cultivated in different regions and belts differ in terms of quality, quantity, speed, taste, and time of harvesting. In plain land regions, typically, crops are harvested in August and September; in malnad areas, they are harvested in December and January. Grown varieties include North Canara rashi, chaali, Gorabalu, idi, Mangalore white chali, and Chikkamagaluru saraku (hasa) bette. Whole unhusked fruit, peeled, boiled, dried, and cooked and spilled nuts are all considered arecanut in Karnataka. Shivamogga is a famous market for boiling splits, or kochooru. In the Sirsi market, mainstays include white chali and rashi, which are boiled, peeled, and dried whole nuts. Mangalore is famous for its complete supari (chaali) which is sun-dried. Arecanut

activities in trading on all marketplaces.

As per the Directorate of Arecanut & Spices Development, Calicut's estimates, around 15 per cent of arecanut is traded by Co-operatives such as CAMPCO Ltd Mangalore, Totgar's Co-operative Sales Society, Sirsi, TUMCOS, Channagiri, Goa Bagayatdar etc. Private traders account for the remaining trade. A substantial quantity of arecanut is traded through APMCs. Though arecanut production is concentrated in several states, its consumption is spread across India. Important assembling markets in the coastal region are Mangalore, Sirsi, Kumta, Cochin, Kasargod, Ponda, Bicholim etc. Gujarat, Uttar Pradesh and Madhya Pradesh are the major consuming states. Major consuming markets are Mumbai, Ahmedabad, Rajkot, Kanpur Indore, Jaipur, Delhi, Nagpur, Patna, Kolkata, Cuttack, Bengaluru and Chennai.

Arecanut displays price volatility influenced by factors such as monsoon patterns, production levels in diverse regions of the country, imports and available trader stocks. Trends in arrivals and prices are related to population growth, money supply, enhanced buying power and overall economic inflation or deflation. Through proper research on price behavior, we can effectively depict the overall direction of change in arecanut prices in different markets.

India is a nation reliant on agriculture. Our conventional farming practices need to be updated in order to keep up with the present. The arrival of the chosen commodities and their rival harvests are the main limitations or factors that affect market prices. The disparities in pricing seen across various markets are known as spatial price variations. These arise from disparities in the locations of commodity production and consumption. Creating a functional agricultural marketing system is essential to increasing farm produce output and supporting overall economic growth. Farming communities are guaranteed fair compensation for their produce thanks to the effective marketing system.

Farmers often experience reduced costs for their produce due to poor timing when bringing crops to market, especially during periods of high supply. This issue arises from an absence of awareness about the best times to sell. Analyzing price trends helps predict fluctuations, allowing farmers to make informed decisions and avoid the negative impacts of overproduction.

2. Methodology

For this study, major arecanut markets were selected based on the maximum arrivals in the market. For the present study, Shivamogga, Sirsi, Sagara, Channagiri, and Yellapura markets were selected as the major arecanut markets in Karnataka which have the maximum arrivals into the market. The monthly data on arrivals (tonnes) and prices (Rs. /Q) of arecanut were collected from the Krishi Marata Vahini and AGMARK websites for the selected markets for the period of 17 years from January 2007 to December 2023. The data on arrivals represents the total arrival (supply) of arecanut (in tonnes) into the market during a month. The data on prices of arecanut represents the modal price (in Rupees/Quintals) of arecanut in a month. Modal price is superior to the monthly average price because it represents the maximum amount of the commodity sold during the particular month in a particular market. To study the trend, the monthly data on arrivals and prices of Arecanut were added to get yearly data for the selected markets.

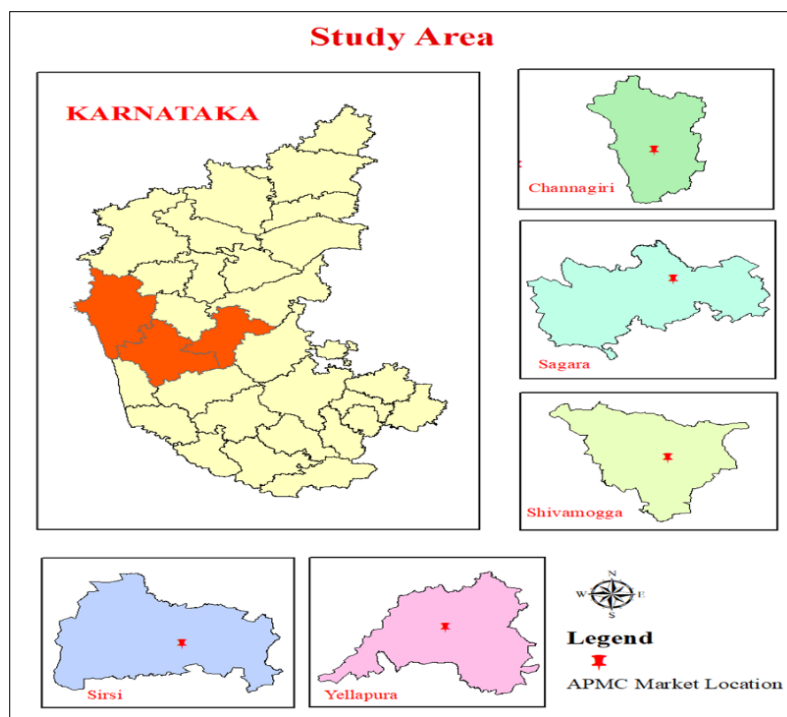


Fig 1: Study Area Map

2.1 To analyze the price behaviour of arecanut in selected markets: Time Series Analysis

Chronologically ordered data of arrivals and prices of arecanut of major markets of India was taken as the database for this time series analysis. Such a type of data is usually conceived of as being generated by certain regulated base causative sources such as long-time forces, cyclical forces (usually with a periodicity of longer duration than a year), annual fluctuation associated with the season of a year, and many other sources of fluctuations producing random effects. The broad idea about, how the value of a variable fluctuates with time can be observed (or studied) by plotting the graph of the time series data. The joint effect of the forces mentioned above causes these fluctuations and sometimes results in a sharp rise and fall. Segregation or separation of these different types of fluctuations in the time series is known as the analysis of time series.

The basic and important components of the time series are:

- Secular trend (T_t)
- Seasonal variation or periodic movements (S_t)
- Cyclical movements (C_t) and
- Irregular movements (I_t)

Secular trend (T_t)

The trend represents the systematic linear or nonlinear changes over a long period of time. It shows a tendency to decrease or increase or stagnate over a period of time. The causes for such changes in time series are due to the technological improvements in the field of study, the growth of the population, and changes in the taste of people, etc.

There are mainly two types of trends namely linear trend and nonlinear trend. The straight line gives the idea about the trend for a shorter period of time. For longer duration, nonlinear trend models were considered to be best to describe the trend.

Seasonal variations (Periodic movements) (S_t)

Many time series exhibit the variation which repeats itself in a particular interval of time within a year. This type of variation is called seasonal variation. The causes for such seasonal variations are climates, customs, etc.

Cyclical movements (C_t)

Cyclical variations or fluctuations in time series data the recurrent variations that are usually longer than one year. Cyclical movements are common in business cycles. For a smaller period of data, if the cyclical variations were not seen then, it is combined with the trend component and it is called the trend-cycle component.

Irregular variations (I_t)

Here, the variations are purely random in nature and it is completely unpredictable. These variations occur due to unknown factors and accidental factors. These unknown factors act unpredictably.

2.2 Analysis of long-term movements

The trend represents the long-term movement without considering the short-term fluctuations in the data. The series obtained ($T = Y/SC$) after eliminating the seasonal component and cyclical component (if any) from the original series of data (Y_t) are used to calculate the trend. If the cyclical component is absent then the trend-cycle component is treated as a trend component. To analyze the trend in arrivals and prices of arecanut, different linear and non-linear models were fitted. The fitted models are shown below:

Linear model

A linear model is one in which all the parameters appear linearly. The average trajectory for the data is a straight line corresponding to an increasing or decreasing constant rate of change in time (Nini *et al.*, 2017) ^[4].

$$Y_t = \beta_0 + \beta_1 t + \varepsilon \quad \dots (1)$$

Quadratic model

A quadratic function is one in which there is a peak or a trough in the data (i.e., parabola). The average trajectory for the data contains a curve with variable degrees of steepness corresponding to an acceleration or deceleration (Nini *et al.*, 2017) ^[4].

$$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \varepsilon \quad \dots (2)$$

Cubic model

The cubic is one in which there are two troughs in the data. The average trajectory for the data behaves quadratically until a further curve occurs, which can correspond to an acceleration or deceleration with variable degrees of steepness (Nini *et al.*, 2017) ^[4].

$$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon \quad \dots (3)$$

where,

β_0 =Intercept or Average effect

β_1 =linear effect parameter

β_2 = Quadratic effect parameter and

β_3 = cubic effect parameter

Y_t =Price in time period 't'

ε =Error term or disturbance term

The coefficients $\beta_0, \beta_1, \beta_2$ and β_3 are constant parameters that need to be estimated. Here, the relation is so derived that the sum of the squared deviations (errors) of the observed values from the theoretical values is the least. The process of minimization of the sum of the squared errors results in some equations called normal equations. The normal equations are the equations, which are used for finding the coefficients of the relation, which is fitted by the method of least square. The above linear models are fitted by using the '*lm*' function in R programming software (Prathima *et al.*, 2024) ^[8].

In the above models, the relationship between the response variable and time period is assumed to be linear or curvilinear. However, the assumptions of linearity, curvilinear or exponential functional form may not hold for the real data in nature. Most of the time series relating to business and economic phenomena over a long period of time do not exhibit sudden growth which is at a constant rate and in a particular direction over a long period of time. Time series are not likely to show either a constant amount of change or a constant ratio of change. The rate of growth is initially slow, and then it picks up and becomes faster and gets accelerated, then becomes stable for some time after which it shows retardation (Prathima *et al.*, 2024) ^[8].

The following are the three nonlinear growth curves, which were used to describe the growth of the present time series:

Exponential model

If the values of t are arranged in an arithmetic series, the corresponding values of y form a geometric series, the relation is of the exponential type. The function of this type can be given by

$$Y_t = \beta_0 \exp(\beta_1 t) + \varepsilon \quad \dots (4)$$

where,

Y_t represents the price in the time period t

β_0 and β_1 are parameters, β_0 represents the value at t = 0,

β_1 represents the exponential rate

ε denotes the error term

Logistic model

If the values of t are arranged in an arithmetic series, the corresponding values of y form a geometric series, the relation is of the logistic type. The function of this type can be given by

$$Y_t = \frac{\beta_0}{(1 + \beta_1 \exp(-\beta_2 t))} + \varepsilon; \beta_1 = \frac{\beta_0}{Y_0} - 1 \quad \dots (5)$$

where,

Y_t represents the price in the time period t

β_0, β_1 and β_2 : are parameters, β_0 represents the carrying capacity or upper asymptote, β_1 represents the initial value,

β_2 represents the growth rate

ε : denotes the error term

Gompertz model

This model is particularly suitable when the growth rate is initially high and then decelerates over time, approaching an upper asymptote. The mathematical form of the Gompertz model is:

$$Y_t = \beta_0 \exp(-\beta_1 \exp(-\beta_2 t)) + \varepsilon; \beta_1 = \ln\left(\frac{\beta_0}{Y_0}\right) \quad \dots (6)$$

Y_t represents the price in the time period t

β_0, β_1 and β_2 : are parameters,

ε : denotes the error term

It may be noted that all the above growth models are 'nonlinear', as each one of these involves at least one parameter in a nonlinear manner. Parameter estimates in nonlinear cases also can be obtained by minimizing the residual sum of squares. However, because of nonlinearity, the resulting normal equations are nonlinear in parameters and so cannot be solved exactly. Accordingly, a number of iterative procedures have been developed to obtain approximate solutions. Four main methods are available in the literature to obtain estimates of the unknown parameters of nonlinear regression models: (i) Linearization method, (ii) Gradient method, (iii) Does not use derivatives (DUD) method, and (iv) Levenberg-Marquardt (LM) method.

The linearization method uses the results of linear least squares theory in a succession of stages. However, the drawback of this procedure is that it may converge very slowly or oscillate widely or may not converge at all. In short, neither this method nor the Gradient method can be recommended in practice. The LM procedure represents a compromise between these methods and combines successfully the best features of both as well as avoids their serious disadvantages. The DUD procedure, as the name suggests, is a derivative-free method. It may be noted that the above growth models are 'nonlinear', which involves at least one parameter in a nonlinear manner. The exponential model was fitted by using the '*SSexpf*' function of the package named '*nlraa*' in R software (Miguez, 2022) ^[3].

Once the parameters of the models were estimated, the best-

fitted model was chosen based on the R^2 and RMSE. The model that has the lowest RMSE and highest R^2 value will be considered the best-fitted model (Prathima *et al.*, 2024) [8].

2.2.1 Test for independence (randomness) of residuals by Run Test

The non-parametric Run test can be used to test the randomness of residuals. A Run is defined as a succession of identical symbols that are followed and preceded by different symbols or no symbols at all. If very few runs occur, a time trend or some bunching owing to lack of independence is suggested and if many runs occur, systematic short-period cyclical fluctuations seem to be influencing the scores.

Null hypothesis (H_0): Sequence is random
Alternative Hypothesis (H_1): Sequence is not random

Let ' n_1 ', be the number of elements of one kind and ' n_2 ' be the number of elements of the other kind in a sequence of $N = n_1 + n_2$ binary events. For small samples *i.e.*, both n_1 and n_2 are equal to or less than 20, if the number of runs r falls between the critical values, we accept the H_0 (null hypothesis) that the sequence of binary events is random otherwise, we reject the H_0 .

For large samples *i.e.*, if either n_1 or n_2 is larger than 15, a good approximation to the sampling distribution of r (runs) is the normal distribution, with

$$\text{Mean } (\mu_r) = \frac{2n_1n_2}{n_1+n_2} + 1 \quad \dots (7)$$

$$\text{Variance } (\sigma_r^2) = \frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1+n_2)^2(n_1+n_2-1)} \quad \dots (8)$$

Then H_0 can be tested using test statistic:

$$Z = \frac{r - \mu_r}{\sigma_r} \sim N(0,1) \quad \dots (9)$$

The significance of any observed value of ' Z ' computed using the equation may be determined from a normal distribution table (Prathima, 2018) [7].

2.2.2 Test for normality of residuals by Shapiro-Wilk's (W) test

This is the standard test for normality. The test statistic W is the ratio of the best estimator of the variance (based on the square of a linear combination of the order statistics) to the usual corrected sum of squares estimation of the variance. W may be thought of as the correlation between given data and their corresponding normal scores. The values of W range from 0 to 1. When $W=1$ the given data are perfectly normal in distribution. When W is significantly smaller than 1, the assumption of normality was not met. A significant W statistic causes us to reject the assumption that the distribution is normal. Shapiro-Wilk's W is more appropriate for small samples up to $n=50$

H_0 : Samples $X_1, \dots, X_n$ is from a normally distributed population.

H_1 : Samples $X_1, \dots, X_n$ is not from a normally distributed

population.

The test statistic is given by:

$$W = \frac{[\sum_{i=1}^n a_i x_{(i)}]^2}{\sum_{i=1}^n (x_{(i)} - \bar{x})^2} \quad \dots (10)$$

where,

$x_{(i)}$ is the i^{th} order statistic, *i.e.*, the i^{th} the smallest number in the sample;

$\bar{x}$ is sample mean

a_i 's are constants, given by

$$(a_1, a_2, \dots, a_n) = \frac{m^T V^{-1}}{\sqrt{(m^T V^{-1} V^{-1} m)}} \quad \dots (11)$$

Where,

$m^T = (m_1, m_2, \dots, m_n)^T$ and $m_1, m_2, \dots, m_n$ are the expected values of the order statistics of independent and identically distributed random variables sampled from the standard normal distribution and V is the covariance matrix of those order statistics. Reject the null hypothesis if W is too small (near to zero) (Prathima, 2018) [7].

2.2.3 Model Adequacy Checking

2.2.3.1 The coefficient of determination (R^2):

The R^2 is a test statistic that will give information about the appropriateness of a model. The R^2 value is the proportion of variability in a data set that is accounted for in the statistical model. It provides a measure of how well the assumed model explains the variability in the dependent variable.

$$R^2 = \frac{RSS}{TSS} = 1 - \frac{ESS}{TSS} \quad \dots (12)$$

The computed R^2 value lies between zero and one. If the R^2 value is closer to 1 indicates that the model fits the data. Adjusted R^2 and RMSE are also used for the checking of the fit of the model.

2.2.3.2 Root Mean Square Error (RMSE)

The RMSE is used to assess the amount of variation that the model is unable to capture in the data. The RMSE is obtained as the square root of the mean squared error and hence considered as the model prediction capability and is obtained as

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (Y_t - \hat{Y}_t)^2}{n}} \quad \dots (13)$$

where,

Y_t = observed value

$\hat{Y}_t$ = predicted value

n = number of observations

3. Results and Discussion

3.1 Analysis of the trend in arrivals and prices of Arecanut in Shivamogga market

In analysing the arrivals and price trends of Arecanut in the Shivamogga market, six different models were tested: linear,

quadratic, cubic, exponential, logistic, and Gompertz.

The analysis of arecanut arrivals in Shivamogga shows no distinct trend along the years tested as shown in Fig 2. The coefficients for all models, especially the higher-order terms, are not statistically significant. While the Cubic model offers a marginally better fit based on low RMSE, the high R^2 values and the lack of significance in the coefficients suggest that factors influencing arrivals may not be adequately captured by these models. Therefore, the arrival patterns appear to be shaped by variables outside the scope of the models used.

Based on the results presented in Table 1, the logistic model emerged as the most suitable model for capturing the price trend, as evidenced by its strong statistical significance and superior fit measures. In this case, the parameters $\beta_0(569.69)$, $\beta_1(7.15)$, $\beta_2(0.20)$ were all significant at the 1 per cent level of significance. The logistic model was evaluated using RMSE and R^2 values, yielding the lowest RMSE (44.32) and the highest R^2 value (0.8916) among the models considered, meaning it explains 89.16 per cent of the variability in arecanut prices. Actual and predicted values of prices by the logistic model are shown in Fig 3.

The logistic model reveals that arecanut prices follow a non-linear growth pattern, with rapid increases initially that gradually slow as they approach an upper limit. It effectively captures both the initial rapid price increases and the expected future stabilization, offering a more nuanced and accurate trend analysis. Panghal *et al.* (2019) [6] employed different non-linear models to estimate the trend of guava for three districts and Haryana state. The study revealed that the logistic model was the best-fitted model for the production of guava fruit in Kurukshetra and Haryana state as a whole.

3.2 Analysis of the trend in arrivals and prices of Arecanut in the Sirsi market

For analysing the arrivals and price trends of arecanut in the Sirsi market, six different models were tested: linear, quadratic, cubic, exponential, logistic, and Gompertz.

The arrival patterns of arecanut in Sirsi do not follow a clear trend based on all the fitted models during the study period as shown in Fig 4. The non-significant coefficients across all models, particularly for the higher-order terms, suggest that there is no evident trend in the data. While the Cubic model shows a slightly better fit in terms of RMSE, the low R^2 values and lack of statistical significance across the coefficients indicate that the arrivals are likely influenced by factors not captured in these models.

Based on the results presented in Table 2, the logistic model emerged as the most suitable model for capturing the price trend, as evidenced by its strong statistical significance and superior fit measures. In this case, the parameters $\beta_0(579.84)$, $\beta_1(7.39)$, $\beta_2(0.19)$ were all significant at the 1 per cent level of significance. The logistic model was evaluated using RMSE and R^2 values, yielding the lowest RMSE (42.95) and the highest R^2 value (0.8916) among the models considered, meaning it explains 89.16% of the variability in Arecanut prices. Actual and predicted values of prices by logistic model are shown in Fig 5.

The logistic model illustrates a non-linear price trend for Arecanut, where prices initially rise quickly but then slow as they approach a saturation point. In practical terms, the logistic model suggests that Arecanut price growth will slow in the future, indicating a move towards market stabilization.

Panghal *et al.* (2019) [6] employed different non-linear models to estimate the trend of guava for three districts and Haryana state. The study revealed that the logistic model was the best-fitted model for the production of guava fruit in Kurukshetra and Haryana state as a whole.

3.3 Analysis of the trend in arrivals and prices of Arecanut in the Sagara market

In examining the arrivals and price trends of arecanut in the Sagara market, six different models were applied: linear, quadratic, cubic, exponential, logistic, and Gompertz.

The arrival patterns of arecanut in Sagara do not seem to follow a clear trend based on the models tested along the study period as shown in Fig 6. The non-significant coefficients across all models, particularly for the higher-order terms, suggest that there is no evident trend in the data. While the Cubic model shows a slightly better fit in terms of RMSE, the low R^2 values and lack of statistical significance across the coefficients indicate that the arrivals are likely influenced by factors not captured in these models.

Based on the results presented in Table 3, the logistic model was determined to be the most accurate for price trend, based on its high significance levels and superior performance metrics. In this case, the parameters $\beta_0(546.28)$, $\beta_1(7.09)$, $\beta_2(0.21)$ were all significant at the 1 per cent level of significance. The logistic model was evaluated using RMSE and R^2 values, yielding the lowest RMSE (41.14) and the highest R^2 value (0.9010) among the models considered, meaning it explains 90.10% of the variability in Arecanut prices. Panghal *et al.* (2019) [6] employed different non-linear models to estimate the trend of guava for three districts and Haryana state. The study revealed that the logistic model was the best-fitted model for the production of guava fruit in Kurukshetra and Haryana state as a whole. Actual and predicted values of prices by logistic model are shown in Fig.7.

The logistic model reveals a non-linear trend in Arecanut prices, with an initial rapid increase followed by a slowdown as the market nears saturation. In conclusion, the logistic model suggests that while Arecanut prices continue to rise, the growth will decelerate, making it a more accurate tool for analyzing price trends in the Sagara market over time.

3.4 Analysis of the trend in arrivals and prices of Arecanut in Channagiri market

In analysing the arrivals and price trends of arecanut in the Channagiri market, six different models were applied: linear, quadratic, cubic, exponential, logistic, and Gompertz.

The arrival patterns of arecanut in Channagiri do not follow a clear trend based on the models tested along the study period as shown in the Fig 8. The non-significant coefficients across all models, particularly for the higher-order terms, suggest that there is no evident trend in the data. While the Cubic model shows a slightly better fit in terms of RMSE, the low R^2 values and lack of statistical significance across the coefficients indicate that the arrivals are likely influenced by factors not captured in these models.

Based on the results presented in the Table 4, the Gompertz model emerged as the most accurate for price trend, based on its high significance levels and superior performance metrics. In the case of the Gompertz model applied to Arecanut prices,

the estimated parameters were highly significant. Specifically, $\beta_0(746.44)$, $\beta_1(2.59)$, $\beta_2(0.10)$. These parameter values indicate important aspects of the price trend, including the maximum price potential, the rapid rate of early price growth, and the point where the growth begins to slow.

When evaluating the Gompertz model using RMSE and R^2 values, it was found to have the lowest RMSE at 41.35 and the highest R^2 value of 0.9069 among all models tested. This means that the Gompertz model explains 90.69 per cent of the variability in Arecanut prices, making it the best fit for the data. The low RMSE suggests that the model minimizes forecasting errors effectively, further underscoring its accuracy. Actual and predicted values of prices by Gompertz model are shown in Fig 9.

The Gompertz model captures a non-linear trend in Arecanut prices in the Channagiri market, with an initial sharp increase followed by a gradual slowdown, reflecting typical commodity market behavior. Early demand spikes push prices upward, but market forces and supply adjustments eventually lead to price stabilization. In summary, the Gompertz model accurately represents the Arecanut price trend in Channagiri, making it a reliable tool for understanding price movements.

3.5 Analysis of the trend in arrivals and prices of Arecanut in Yellapura market

In analysing the arrivals and price trends of Arecanut in the Yellapura market, six different models were tested: linear, quadratic, cubic, exponential, logistic, and Gompertz.

The arrival patterns of arecanut in Yellapura do not seem to follow a clear trend based on the models tested along the

study period as shown in the Fig 10. The non-significant coefficients across all models, particularly for the higher-order terms, suggest that there is no evident trend in the data. While the Cubic model shows a slightly better fit in terms of RMSE, the low R^2 values and lack of statistical significance across the coefficients indicate that the arrivals are likely influenced by factors not captured in these models.

Based on the results presented in Table 5, the logistic model emerged as the most suitable model for capturing the price trend, as evidenced by its strong statistical significance and superior fit measures. In this case, the parameters $\beta_0(603.34)$, $\beta_1(7.45)$, $\beta_2(0.20)$ were all significant at the 1 per cent level of significance. The logistic model was evaluated using RMSE and R^2 values, yielding the lowest RMSE (41.35) and the highest R^2 value (0.9110) among the models considered, meaning it explains 89.16% of the variability in Arecanut prices. Panghal *et al.* (2019) [6] employed different non-linear models to estimate the trend of guava for three districts and Haryana state. The study revealed that the logistic model was the best-fitted model for the production of guava fruit in Kurukshetra and Haryana state as a whole. Actual and predicted values of prices by logistic model are shown in Fig 11.

The logistic model shows a non-linear trend where Arecanut prices rise sharply at first, but the growth slows over time, eventually reaching a saturation point. This mirrors real-world market conditions, where high demand initially drives prices up before supply adjustments lead to stabilization. The model suggests that while prices are increasing, future growth will decelerate, making it a more accurate representation of price trends in the Yellapura market compared to linear, quadratic, cubic, or exponential models.

Table 1: Parameter estimates of fitted models for arrivals (Tonnes) and prices (00'Rs. /Q) of arecanut in the Shivamogga market

Parameters	Shivamogga arrivals						Shivamogga prices					
	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz
Intercept (β_0)	149.79**	90.81 ^{NS}	56.76 ^{NS}	153.63**	191.42**	191.41**	42.58 ^{NS}	54.48 ^{NS}	90.76 ^{NS}	111.30**	569.69**	766.85 ^{NS}
β_1	2.95 ^{NS}	21.58 ^{NS}	41.49 ^{NS}	0.01 ^{NS}	0.59 ^{NS}	1.09 ^{NS}	25.88**	22.12 ^{NS}	0.91 ^{NS}	0.09**	7.15**	2.5**
β_2	-	-1.03 ^{NS}	-3.72 ^{NS}	-	0.83 ^{NS}	0.51 ^{NS}	-	0.20 ^{NS}	3.07 ^{NS}	-	0.20**	0.09 ^{NS}
β_3	-	-	0.09 ^{NS}	-	-	-	-	-	-0.10 ^{NS}	-	-	-
R^2	0.05	0.18	0.20	0.04	0.16	0.16	0.8867	0.8878	0.8929	0.8617	0.8916	0.8913
RMSE	60.49	56.31	55.58	60.66	56.83	56.92	45.32	45.1	44.06	50.06	44.32	44.39
Runs test (p-value)	-0.85 ^{NS} (0.39)	-1.25 ^{NS} (0.20)	-0.03 ^{NS} (0.97)	-0.85 ^{NS} (0.39)	-1.74 ^{NS} (0.08)	0.05 ^{NS} (0.95)	0.26 ^{NS} (0.79)	0.26 ^{NS} (0.79)	-0.23 ^{NS} (0.81)	-0.97 ^{NS} (0.33)	-0.23 ^{NS} (0.81)	-0.23 ^{NS} (0.81)
Shapiro-Wilk (p-value)	0.50 (<0.01)	0.62 (<0.01)	0.59 (<0.01)	0.51 (<0.01)	0.50 (<0.01)	0.49 (<0.01)	0.95 ^{NS} (0.49)	0.93 ^{NS} (0.26)	0.91 ^{NS} (0.10)	0.90 ^{NS} (0.25)	0.94 ^{NS} (0.29)	0.94 ^{NS} (0.32)

Note: ** and * indicates significant at one and five per cent, respectively; NS - Non-Significant

Table 2: Parameter estimates of fitted models for arrivals (Tonnes) and prices (00'Rs. /Q) of arecanut in the Sirsi market

Parameters	Sirsi arrivals						Sirsi prices					
	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz
Intercept (β_0)	62.44**	39.35**	0.488 ^{NS}	62.57**	67.41**	67.31**	37.43 ^{NS}	53.27 ^{NS}	78.04 ^{NS}	104.18**	579.84**	809.66 ^{NS}
β_1	0.13 ^{NS}	7.42 ^{NS}	30.15*	0.001 ^{NS}	0.71 ^{NS}	1.01 ^{NS}	25.10**	20.09 ^{NS}	5.61 ^{NS}	0.09**	7.39**	2.59**
β_2	-	-0.41 ^{NS}	-3.47 ^{NS}	-	0.49 ^{NS}	0.65 ^{NS}	-	0.27 ^{NS}	2.23 ^{NS}	-	0.19**	0.09 ^{NS}
β_3	-	-	0.11 ^{NS}	-	-	-	-	-	-0.07 ^{NS}	-	-	-
R^2	0.0007	0.1323	0.3183	0.00066	0.09	0.0893	0.8883	0.8904	0.8929	0.8676	0.8916	0.8923
RMSE	23.85	22.23	19.7	23.85	22.74	22.76	43.6	43.2	42.7	47.45	42.95	42.8
Runs test (p-value)	-1.74 ^{NS} (0.08)	-1.03 ^{NS} (0.30)	-1.24 ^{NS} (0.21)	-1.74 ^{NS} (0.08)	-1.24 ^{NS} (0.21)	-1.24 ^{NS} (0.21)	-0.64 ^{NS} (0.52)	-0.64 ^{NS} (0.52)	0.39 ^{NS} (0.69)	-0.97 ^{NS} (0.33)	-0.23 ^{NS} (0.81)	-0.23 ^{NS} (0.81)
Shapiro-Wilk (p-value)	0.84 (0.008)	0.85 (0.01)	0.82 (0.004)	0.84 (0.008)	0.88 ^{NS} (0.03)	0.88 ^{NS} (0.03)	0.96 ^{NS} (0.71)	0.93 ^{NS} (0.26)	0.93 ^{NS} (0.22)	0.84 ^{NS} (0.017)	0.95 ^{NS} (0.25)	0.93 ^{NS} (0.29)

Note: ** and * indicates significant at one and five per cent, respectively; NS - Non-Significant

Table 3: Parameter estimates of fitted models for arrivals (Tonnes) and prices (00'Rs. /Q) of arecanut in the Sagara market

Parameters	Sagara arrivals						Sagara prices					
	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz
Intercept (β_0)	35.65**	22.64*	18.29 ^{NS}	39.07**	64.71**	65.29**	42.60 ^{NS}	50.93 ^{NS}	89.80 ^{NS}	109.99**	546.28**	718.32*
β_1	2.08*	6.19 ^{NS}	8.74 ^{NS}	0.04*	0.35 ^{NS}	1.16 ^{NS}	25.26**	22.63*	-0.09 ^{NS}	0.08**	7.09**	2.49**
β_2	-	-0.23 ^{NS}	-0.57 ^{NS}	-	1.82 ^{NS}	0.28 ^{NS}	-	0.14 ^{NS}	3.21 ^{NS}	-	0.21**	0.10*
β_3	-	-	0.01 ^{NS}	-	-	-	-	-	-0.11 ^{NS}	-	-	-
R ²	0.3174	0.3897	0.3938	0.2925	0.3935	0.3918	0.8956	0.8961	0.9023	0.8648	0.9010	0.9002
RMSE	14.98	14.16	14.12	15.25	14.11	14.14	42.26	42.15	40.87	47.7	41.14	41.31
Runs test (p-value)	-0.23 ^{NS} (0.81)	-1.24 ^{NS} (0.21)	-0.73 ^{NS} (0.45)	-0.23 ^{NS} (0.81)	0.26 ^{NS} (0.79)	0.26 ^{NS} (0.79)	-0.64 ^{NS} (0.52)	-0.61 ^{NS} (0.54)	0.39 ^{NS} (0.69)	-0.97 ^{NS} (0.33)	0.26 ^{NS} (0.79)	0.26 ^{NS} (0.79)
Shapiro-Wilk (p-value)	0.66 (<0.01)	0.72 (<0.01)	0.72 (<0.01)	0.66 (<0.01)	0.72 (<0.01)	0.71 (<0.01)	0.94 ^{NS} (0.42)	0.93 ^{NS} (0.27)	0.90 ^{NS} (0.07)	0.86 ^{NS} (0.02)	0.92 ^{NS} (0.16)	0.93 ^{NS} (0.26)

Note: ** and * indicates significant at one and five per cent, respectively; NS - Non-Significant

Table 4: Parameter estimates of fitted models for arrivals (Tonnes) and prices (00'Rs. /Q) of arecanut in the Channagiri market

Parameters	Channagiri arrivals						Channagiri prices					
	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz
Intercept (β_0)	86.96**	76.47 ^{NS}	118.10 ^{NS}	90.36**	149.91 ^{NS}	157.00 ^{NS}	35.28 ^{NS}	46.14 ^{NS}	78.57 ^{NS}	107.08**	562.62**	746.44*
β_1	3.19 ^{NS}	6.51 ^{NS}	-17.83 ^{NS}	0.02 ^{NS}	0.13 ^{NS}	0.67 ^{NS}	26.28**	22.85*	3.89 ^{NS}	0.09**	0.21**	2.59**
β_2	-	-0.18 ^{NS}	3.10 ^{NS}	-	-0.98 ^{NS}	0.09 ^{NS}	-	0.19 ^{NS}	2.75 ^{NS}	-	9.39**	0.10*
β_3	-	-	-0.12 ^{NS}	-	-	-	-	-	-0.09 ^{NS}	-	-	-
R ²	0.07	0.08	0.12	0.07	0.08	0.08	0.9027	0.9036	0.9076	0.8747	0.9067	0.9069
RMSE	54.00	53.86	52.72	54.08	53.88	53.9	42.28	42.08	41.19	47.96	41.38	41.35
Runs test (p-value)	-0.73 ^{NS} (0.45)	-0.73 ^{NS} (0.45)	0.26 ^{NS} (0.79)	-0.73 ^{NS} (0.45)	-0.73 ^{NS} (0.45)	-0.73 ^{NS} (0.45)	-0.64 ^{NS} (0.52)	-0.68 ^{NS} (0.50)	-1.24 ^{NS} (0.21)	-0.97 ^{NS} (0.33)	-1.24 ^{NS} (0.21)	-0.64 ^{NS} (0.52)
Shapiro-Wilk (p-value)	0.76 (<0.01)	0.79 (0.001)	0.76 (<0.01)	0.75 (<0.01)	0.78 (<0.01)	0.77 (<0.01)	0.95 ^{NS} (0.51)	0.93 ^{NS} (0.26)	0.91 ^{NS} (0.10)	0.83 ^{NS} (0.006)	0.90 ^{NS} (0.23)	0.94 ^{NS} (0.32)

Note: ** and * indicates significant at one and five per cent, respectively; NS - Non-Significant

Table 5: Parameter estimates of fitted models for arrivals (Tonnes) and prices (00'Rs. /Q) of arecanut in the Yellapura market

Parameters	Yellapura arrivals						Yellapura prices					
	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz	Linear	Quadratic	Cubic	Exponential	Logistic	Gompertz
Intercept (β_0)	44.72**	29.06 ^{NS}	12.24 ^{NS}	45.28**	52.60 ^{NS}	52.56 ^{NS}	39.85 ^{NS}	55.93 ^{NS}	93.25 ^{NS}	111.90**	603.34**	833.56 ^{NS}
β_1	0.50 ^{NS}	5.45 ^{NS}	15.28 ^{NS}	0.009 ^{NS}	0.61 ^{NS}	0.93 ^{NS}	26.92**	21.84*	0.02 ^{NS}	0.09**	7.45**	2.58**
β_2	-	-0.27 ^{NS}	-1.60 ^{NS}	-	0.39 ^{NS}	0.55 ^{NS}	-	0.28 ^{NS}	3.22 ^{NS}	-	0.20**	0.09 ^{NS}
β_3	-	-	0.04 ^{NS}	-	-	-	-	-	-0.10 ^{NS}	-	-	-
R ²	0.01	0.11	0.17	0.01	0.1	0.09	0.9055	0.9074	0.9125	0.8826	0.911	0.9106
RMSE	18.34	17.38	16.8	18.36	17.56	17.57	42.61	42.18	41	47.49	41.35	41.44
Runs test (p-value)	-2.75 (<0.01)	-2.24 ^{NS} (0.02)	-1.24 ^{NS} (0.21)	-1.74 ^{NS} (0.08)	-1.24 ^{NS} (0.21)	-1.24 ^{NS} (0.21)	-0.64 ^{NS} (0.52)	-0.67 ^{NS} (0.50)	-0.23 ^{NS} (0.81)	-1.15 ^{NS} (0.24)	0.26 ^{NS} (0.79)	0.26 ^{NS} (0.79)
Shapiro-Wilk (p-value)	0.57 (<0.01)	0.65 (<0.01)	0.60 (<0.01)	0.58 (<0.01)	0.58 (<0.01)	0.57 (<0.01)	0.95 ^{NS} (0.50)	0.93 ^{NS} (0.30)	0.95 ^{NS} (0.49)	0.85 ^{NS} (0.011)	0.94 ^{NS} (0.41)	0.94 ^{NS} (0.41)

Note: ** and * indicates significant at one and five per cent, respectively; NS - Non-Significant

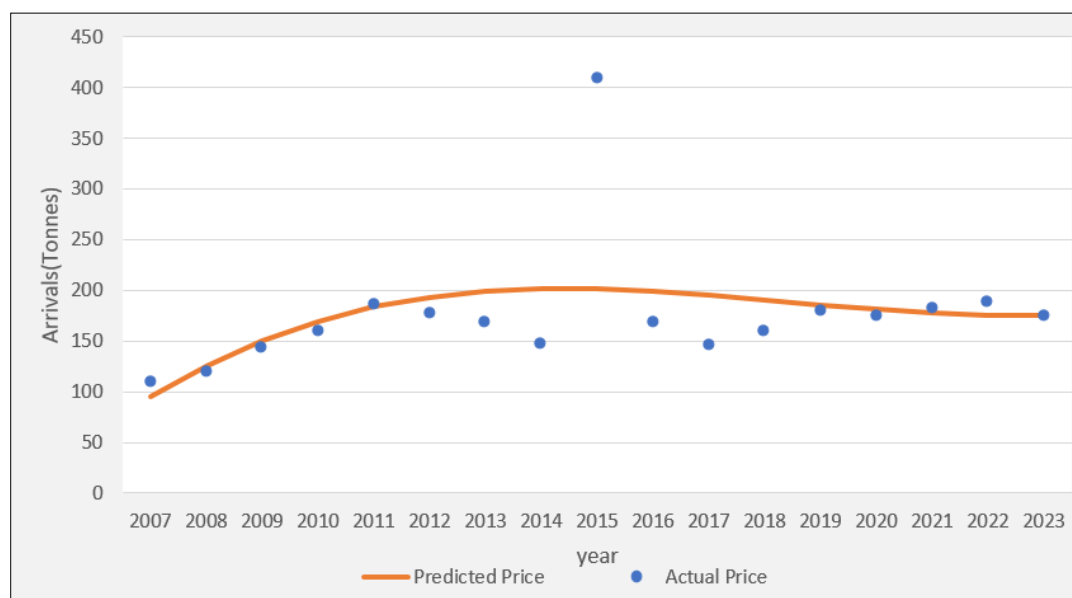
**Fig 2:** Best-fitted model for arrivals of arecanut in Shivamogga market



Fig 3: Best-fitted logistic model for prices of arecanut in Shivamogga market

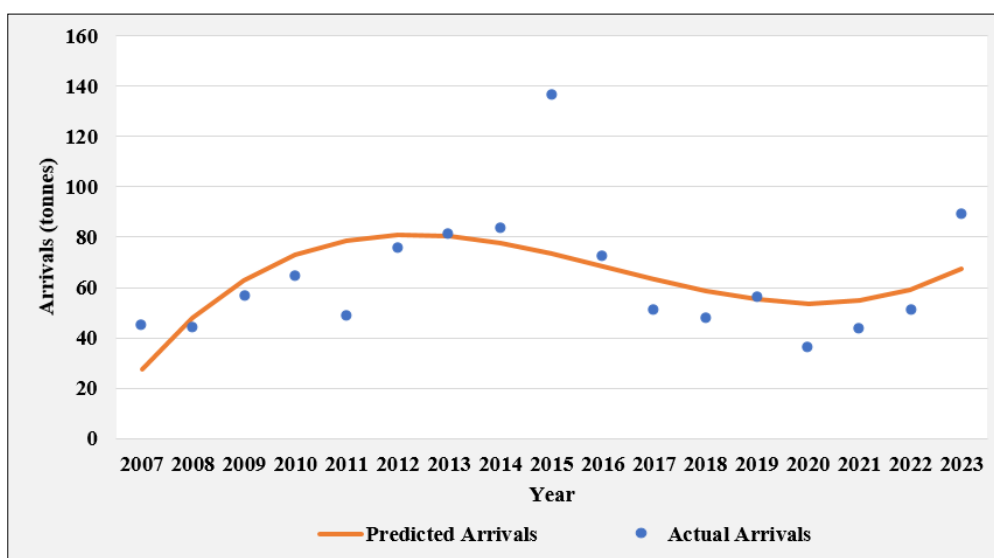


Fig 4: Best-fitted model for arrivals of arecanut in the Sirsi market

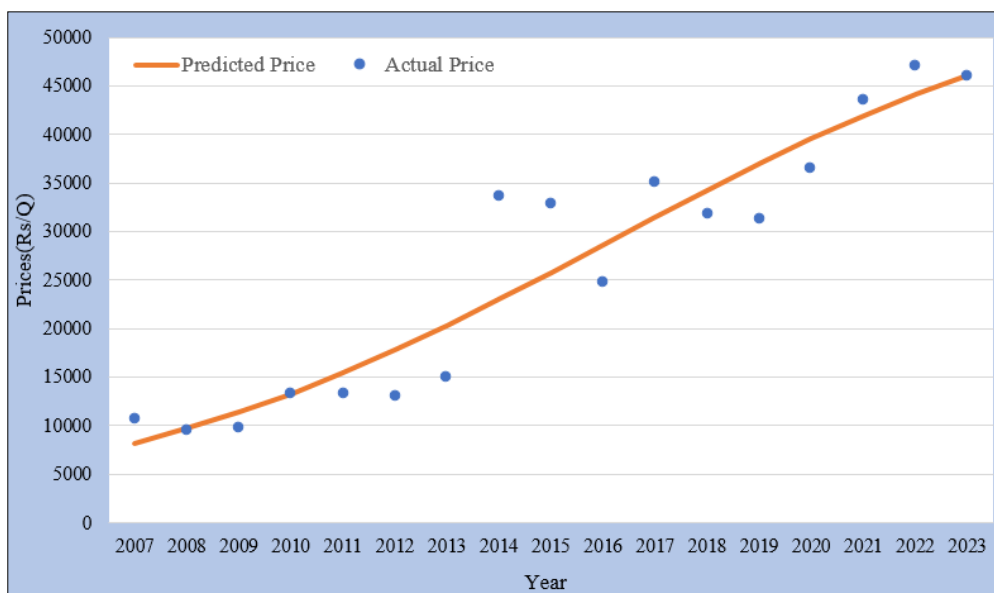


Fig 5: Best-fitted logistic model for prices of arecanut in Sirsi market

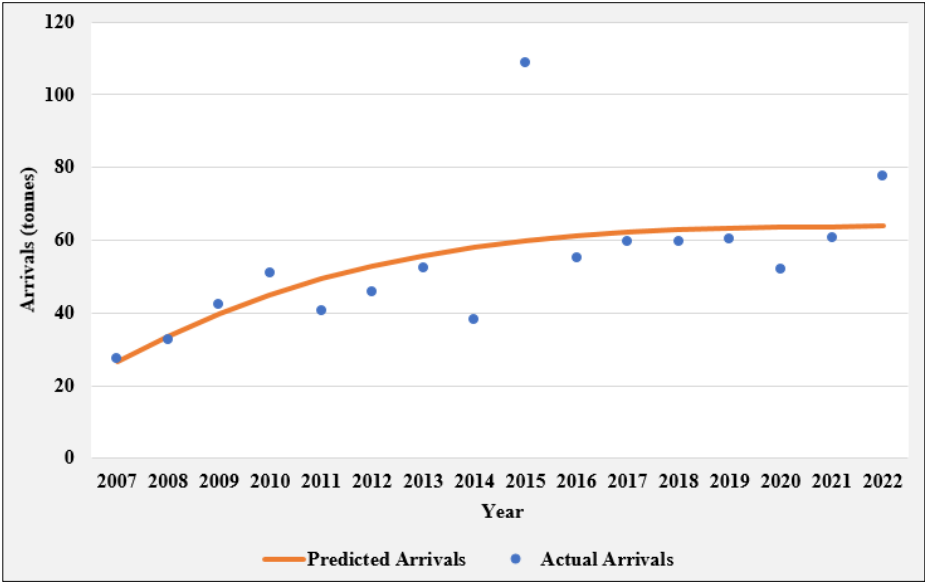


Fig 6: Best-fitted model for arrivals of arecanut in Sagara market

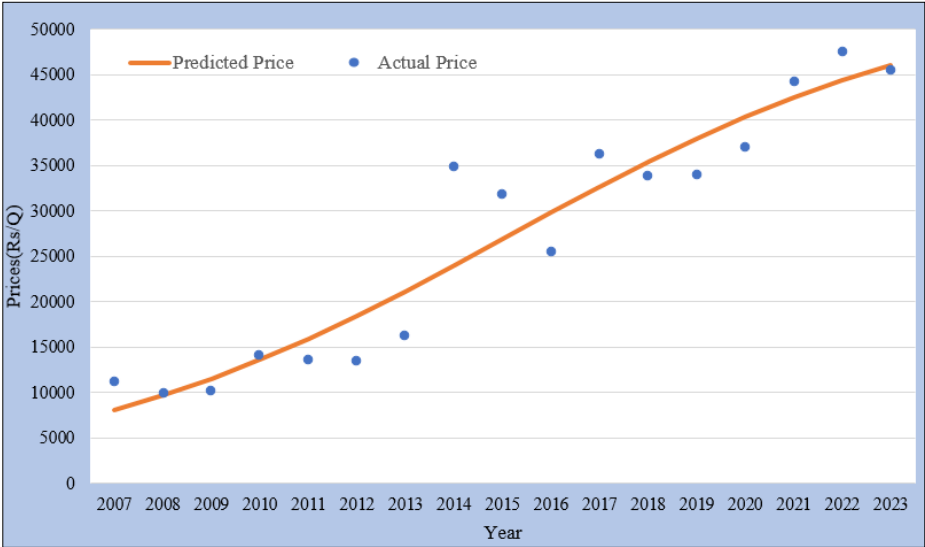


Fig 7: Best-fitted logistic model for prices of arecanut in Sagara market

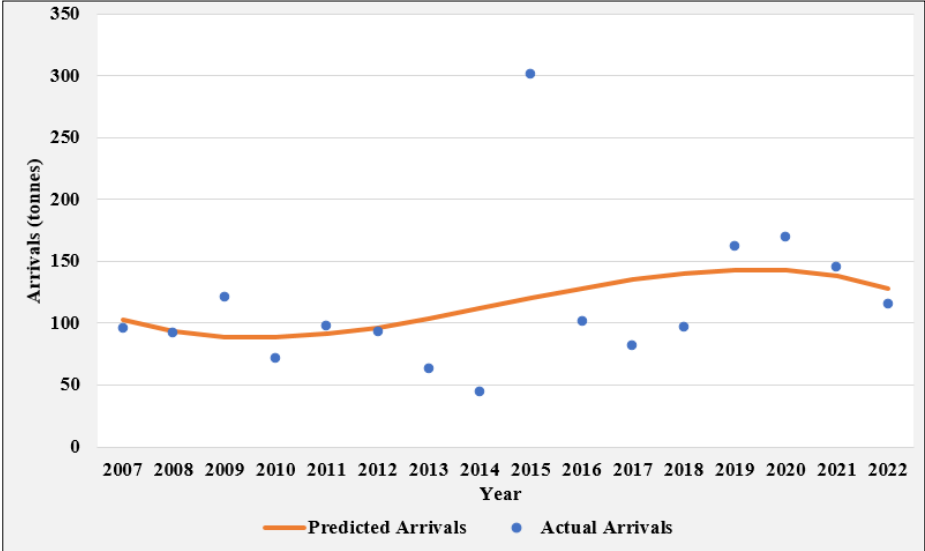


Fig 8: Best-fitted model for arrivals of arecanut in Channagiri market

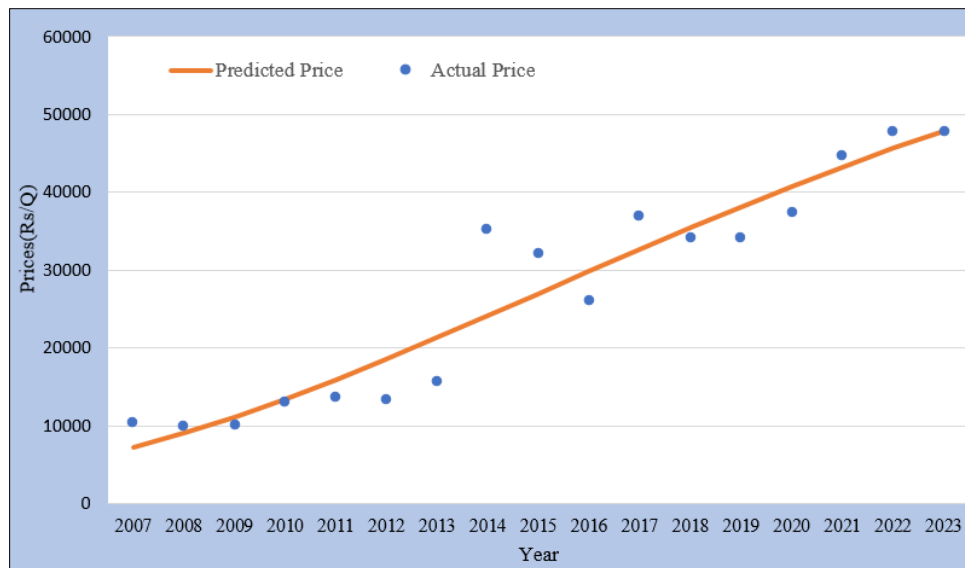


Fig 9: Best-fitted Gompertz model for prices of arecanut in Channagiri market

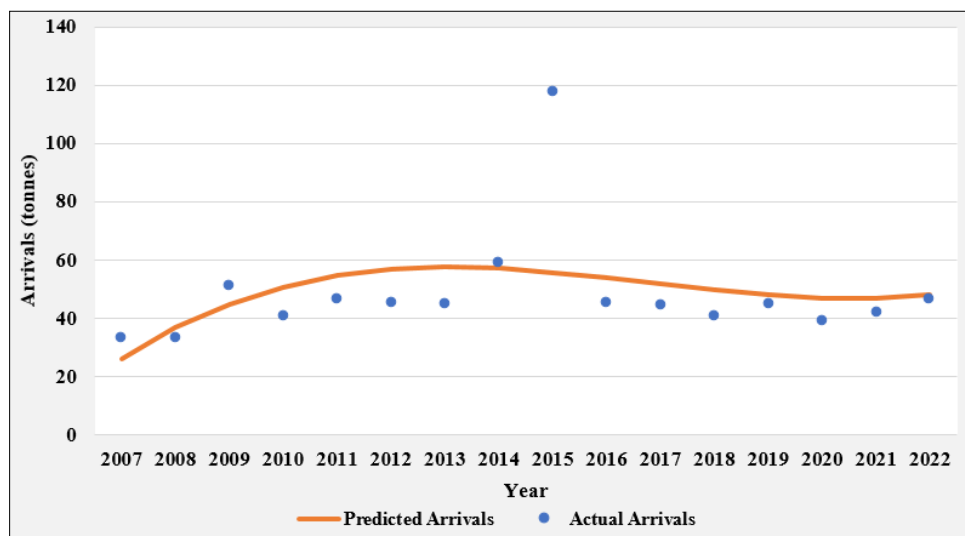


Fig 10: Best-fitted model for arrivals of arecanut in the Yellapura market

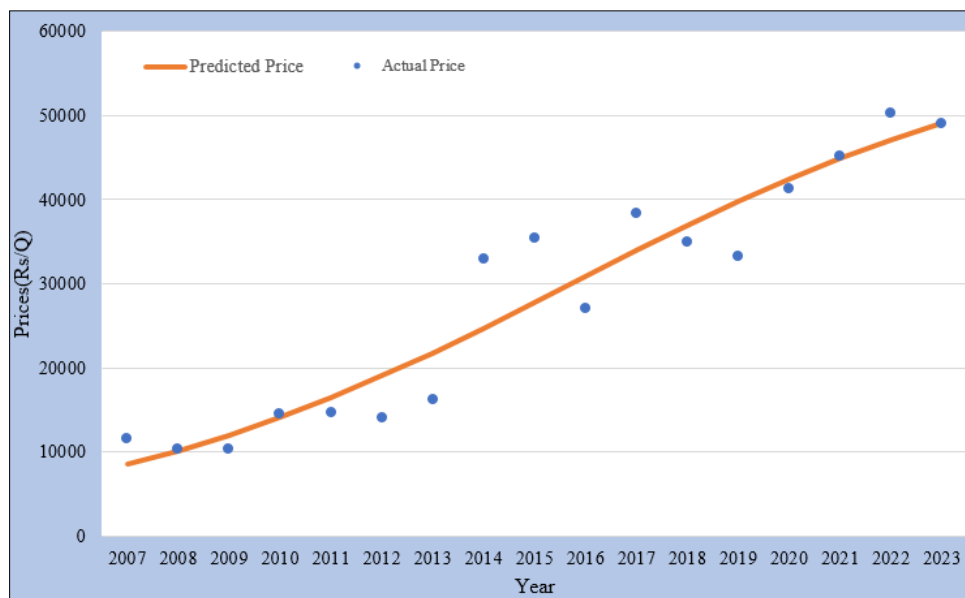


Fig 11: A best-fitted logistic model for prices of arecanut in the Yellapura market

4. Conclusion

To study the trend in arrivals and prices of arecanut in selected markets, linear models viz. linear model, quadratic model, cubic model, and nonlinear model i.e., exponential model, logistic model and Gompertz model were fitted. RMSE and R^2 values were considered to check the adequacy of the fitted models.

Across all markets, no distinct trends were observed in the arrivals of arecanut. This lack of trend suggests that arrivals are influenced by external factors such as weather conditions, agricultural practices, market demand, and policy interventions, which are not captured by the tested models. The marginally better fit of the cubic model in some cases highlights variability but does not indicate any significant patterns.

The logistic model proved to be the most effective for analyzing price trends in Shivamogga, Sirsi, Sagara, and Yellapura markets, capturing the non-linear growth pattern of prices. This model demonstrated significant coefficients, high R^2 values, and low RMSE, indicating its robustness in explaining the price dynamics. The results suggest rapid price increases initially, followed by a stabilization as prices approach saturation levels.

The Gompertz model provided the best fit for price trends in Channagiri market, offering similarly significant insights into the price behavior, with early rapid growth followed by gradual stabilization.

Overall, the results highlight that there is no trend in arrivals of arecanut in major markets of Karnataka and there is an increasing trend in prices of arecanut in major markets of Karnataka.

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